Runoff, Erosion, and Restoration Studies in Piñon-Juniper Woodlands of the Southeastern Jemez Mountains

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Piñon-juniper woodlands are one of the most extensive vegetation types in New Mexico, including large portions of Bandelier National Monument and the Pajarito Plateau in the southeastern Jemez Mountains. The woodland soils on local mesas formed to a large degree under different vegetation during cooler, moister conditions of the late Pleistocene; in other words, they are over 10,000 years old, and many are over 100,000 years old (McFadden et al. 1996). Changes in climate and vegetation in the early Holocene (9,000–6,000 years ago) led to at least localized episodes of soil erosion on adjoining uplands (Reneau and McDonald 1996, Reneau et al. 1996). During this time, the dominant climatic and associated vegetation patterns of the modern southwestern United States developed , including grasslands, piñon-juniper woodlands and ponderosa pine savannas and forests (Allen et al. 1998). On the basis of local fire history information (Allen 2002), the young ages of most piñon-juniper trees here (Julius 1999, unpublished data), and soils data (McFadden 1996), we believe that many upland mesa areas now occupied by dense piñon-juniper woodlands were formerly more open, with fewer trees and well-developed herbaceous understories that: 1) protected the soil from excessive erosion during intense summer thunderstorm events, and 2) provided a largely continuous fuel matrix, which allowed surface fires to spread and maintain these vegetation types (Figure 1). In contrast, rocky canyon walls have probably changed relatively little through the centuries, as grazing and fire suppression had fewer effects on such sites.

Native American effects on local woodlands are thought to have been insignificant or highly localized until the late 12th century, when the Ancestral Puebloan population began to intensively occupy and utilize the Bandelier area (Powers and Orcutt 1999). Piñon-juniper woodlands were the core area of prehistoric occupation by these prehistoric agriculturalists – most of the over 2500 archaeological sites recorded in the ~50% of the park surveyed to date are found in piñon-juniper woodland settings. Cutting and burning of piñon -juniper trees for cooking, heating, building and agricultural activities likely led to significant deforestation of upland mesas from about 1150-1550 A.D. (Allen – in review). Thus, Ancestral Puebloan land use practices favored herbaceous vegetation. Intensive soil disturbance certainly occurred in farmed areas and around habitations, but there was probably little net change in landscape-wide erosion rates due to the small size and dispersed locations of fields and villages.

Figure 1. Grassy ground cover and surface fires once maintained more open conditions in many piñon -juniper woodland settings.

EuroAmerican settlement of the adjoining Rio Grande Valley and the introduction of domestic livestock grazing began in 1598. It is unlikely, however, that significant livestock grazing (that is, with substantial widespread effects on the herbaceous understory, fire regime, or erosion rates) took place in much of Bandelier until railroads linked the Southwest to commercial markets in the 1880s. Millions of sheep and cattle were placed in the New Mexico landscape at that time, with unrestricted grazing on public lands. Livestock grazing continued in Bandelier until 1932, and feral burros were similarly allowed to cause grazing impacts until about 1980 (Allen 1989). Sharp reductions in the herbaceous ground cover and associated organic litter resulted (Figure 2), effectively suppressing previously widespread surface fires (in concert with institutionalized fire suppression initiated by the federal government after 1910). Severe drought during the 1950's contributed to declines in ground cover (Allen and Breshears 1998). Fire-sensitive piñon and juniper trees became established in densities unprecedented for at least the past 800 years. As these trees grew, they became increasingly effective competitors for water and nutrients. Thus, a positive feedback cycle was initiated that favors tree invasion and decreased herbaceous ground cover on mesa tops (Allen 1989:246-251, Gottfried et al. 1995).

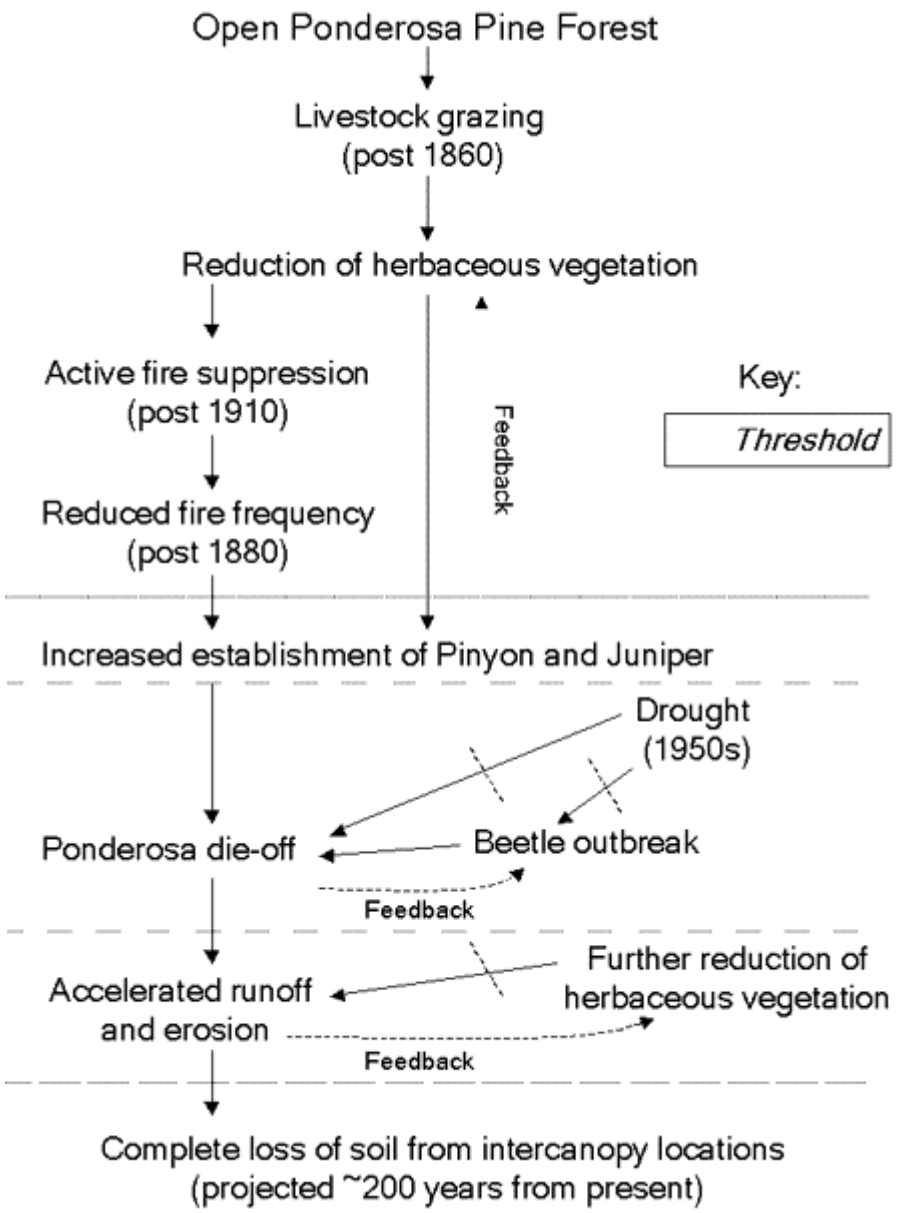

Figure 2. Historic changes in forest/woodland border (ecotone) areas on Frijolito Mesa, Bandelier National Monument (Davenport et al. 1998, Allen and Breshears 1998). Short-dotted lines represent ecological thresholds.

This land use history has caused the degraded and unsustainable ecosystem conditions observed in many piñon-juniper woodlands today. Intensive watershed research over the past decade, involving collaborations among Los Alamos National Laboratory, U.S. Geological Survey, Colorado State University, U.S. Forest Service, and Bandelier National Monument, shows that the intercanopy soils of Bandelier's woodlands are apparently eroding at net rates of about one centimeter per decade (Wilcox et al. 1996a/b, Davenport et al. 1998, Hastings et al. – in review, CD Allen – unpublished data). Given soil depths averaging only one to two feet in many areas, there will soon be loss of entire soil bodies across extensive areas (Figure 3). Also, this accelerated runoff and erosion is damaging thousands of archeological sites at Bandelier; over 90% of inventoried archeological sites are being damaged by soil erosion (Powers and Orcutt 1999, Bandelier National Monument – unpublished data). For example, we have found as many as 1040 cultural artifacts (mostly potsherds) moved by a single thunderstorm into a sediment trap draining only ¼ acre of gentle hillslope (Figure 4). To a significant degree, the Park's biological productivity and cultural resources are literally washing away, posing major management challenges (Sydoriak et al. 2000). Similar histories and high erosion rates likely characterize many piñon-juniper woodlands in New Mexico (Gottfried et al. 1995, Bogan et al. 1998), resulting in considerable transport of sediment through watersheds, with associated impacts on water quality.

Figure 3. Bare soil and high erosion rates characterize the desertified interspaces between piñon –juniper trees across large areas of the Pajarito Plateau. Note the exposed roots.

Ecological thresholds have apparently been crossed (Figure 2) such that harsh physical processes are now dominant across Bandelier's degraded piñon-juniper woodlands (Allen 1989: 246-250, Gottfried et al. 1995, Davenport et al. 1998). The loss of organic-rich topsoils, decreased plant-available-water (Breshears and Barnes 1999), extreme soil surface temperatures, and freeze-thaw activity severely impede herbaceous vegetation establishment and productivity (Davenport et al. 1998). Reductions in ground cover cause increased runoff from summer thunderstorms (Reid at al. 1999), with associated increases in erosion (Wilcox at al. 1996a, b, in press). Re-establishment of herbaceous ground cover under today's desertified mesa-top conditions may also be difficult due to depleted soil seed banks, highly efficient seed predators (particularly harvester ants; Snyderman and Jacobs 1995), and an unnaturally large elk population (Allen 1996). Herbivore exclosures established in 1975 show that protection from grazing, by itself, fails to promote vegetative recovery in Bandelier's piñon-juniper ecosystems (Chong 1992; Potter 1985). Without management intervention, this human-induced episode of accelerated soil erosion appears to be highly persistent and irreversible (Davenport et al. 1998, Wilcox et al. – in press).

Figure 4.Immense numbers of ceramic and lithic artifacts are being transported by accelerated runoff and erosion at Bandelier, degrading the cultural resources for which the park was established.

Happily, experimentation over the past decade shows that a simple, though labor-intensive, treatment can restore more stable ecological conditions (Chong 1994, Jacobs and Gatewood 1999; Loftin 1999, Jacobs et al. 2000, Hastings et al. – in review). By cutting many smaller piñon and juniper trees, and lopping and scattering the branches across the barren interspaces between trees, herbaceous ground cover and soil stability increase markedly (Figures 5 and 6). It is likely that application of similar methods would restore more sustainable conditions to degraded piñon-juniper woodlands throughout the Southwest. Many of the ecological considerations developed for restoration other forest types in this region (Allen et al. – in press) are also relevant to the restoration of semiarid woodlands.

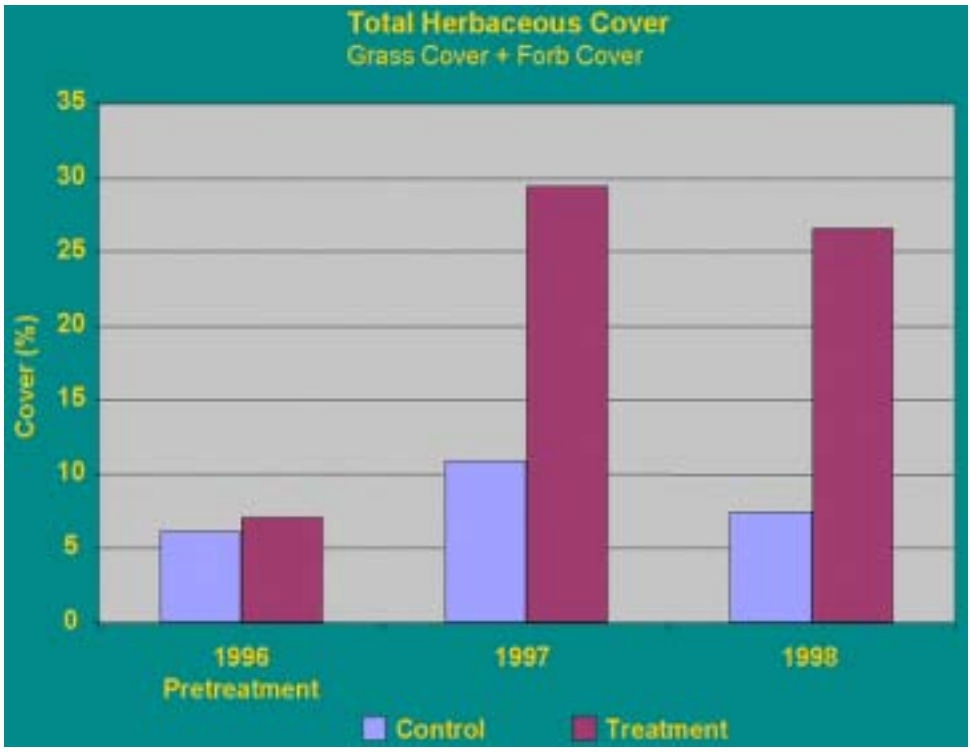

Figure 5. Herbaceous cover response to restoration treatment on Frijolito Mesa (Jacobs et al. 2000).

Figure 6. View of herbaceous cover response to restoration treatment after first growing season.

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